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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE EXAMINING CORPS**

**IN RE APPLICATION OF
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FOR A
PRINTED CIRCUIT BOARD-BASED CURRENT SENSOR**

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PRINTED CIRCUIT BOARD-BASED CURRENT SENSOR

Description

The invention relates to a device for measuring AC currents in the form of a current sensor according to the preamble to claim for protection 1.

Prior Art

Inductive measuring procedures according to the Rogowski principle are known in the area of current measuring technology. In the known models, the current-carrying conductor is routed through a coil. The sensor coil can here vary in design. One design was described in DE 195 05 812 C2, in which an electrically insulating annular element is provided as the winding carrier. However, the disadvantage to this design is that production requires numerous different steps. Another disadvantage is that, when setting up a current sensor with an integrated electronic evaluation or calculation circuit, the coil in the form described in DE 195 05 812 C2 as a component in addition to the electronic components of the evaluation or calculation circuit have to be placed, secured and electrically connected. Therefore, the integration of this coil into an electronic evaluation or corrective calculation circuit is associated with a high space requirement and high costs for manufacturing the device as a whole. The additional requirement that sensors be miniaturized to make increasingly smaller models tailored to the respective application available cannot be met with a current acquisition coil according to DE 195 05 812 C2. In the description of another design according to US 5,414,400, the coil is fabricated directly on a printed circuit board using the printed conductors and through platings. Viewed in a radial direction, the printed circuit board segment between

1 the through platings here forms the electrically insulating annular element or annular segment.
2 The printed conductors are oriented in such a way that the respective printed conductor on the
3 top of the printed circuit board ends in a through plating for establishing an electrical
4 connection with a printed conductor on the bottom, while the latter in turn ends in a through
5 plating for establishing an electrical connection with an additional printed conductor on the
6 top, thereby representing a winding around the insulating annular segment. The geometric
7 orientation of the printed conductors yields a coil-like winding of the insulating annular
8 segment, which, in its entirety, results in a current acquisition coil according to the Rogowski
9 principle. The key disadvantage to the design described in US 5,414,400 is that the current-
10 carrying conductor must also be routed through the borehole enveloped by the coil. As a
11 result, a current acquisition coil given this design cannot be placed around a current-carrying
12 conductor for purposes of current acquisition at a later time. Another disadvantage is that the
13 coil as designed has a go-and-return type of winding. It is proposed that the current acquisition
14 coil be built around a two-layer printed circuit board, whose windings are quite symmetrically
15 arranged over the entirety, but the individual windings alternate in dimensions. This
16 disadvantages stems from the geometric requirement that the windings for practically two coils
17 lying one inside the other be flatly accommodated on a printed circuit board.

18 Object

19 The object of the invention is to realize an inexpensive, compact design for a device
20 for measuring AC currents by means of a current acquisition coil based on a printed circuit
21 board or a printed circuit board segment according to the Rogowski principle, which can at a
22 later point be placed around and encompass the current-carrying conductor without

1 interrupting the function of the current-carrying conductor. The structure of the windings must
2 here be very symmetrical in order to achieve a high measuring accuracy.

3 Solution

4 The object is achieved according to the invention by virtue of the features cited in
5 claim 1.

6 The device according to the invention for a current acquisition coil is realized with the
7 help of a printed circuit board, which can be flipped open in such a way that the current-
8 carrying conductor to be measured can also be inserted in the provided area of the coil without
9 interrupting or deactivating the current-carrying conductor. The opened device for a current
10 acquisition coil is closed for measurement in such a way that the current-carrying conductor
11 is completely enclosed by the current acquisition coil, and the current acquisition coil can
12 measure the current of the current-carrying conductor according to the Rogowski principle. To
13 satisfy additional requirements on the current acquisition coil relating to symmetrical structure
14 or compactness, a multi-layer printed circuit board must be used. This offers more ways in
15 which to control the printed conductor, and enables the most symmetrical structure possible
16 for the current acquisition coil winding.

17 The printed circuit board of the device for measuring AC currents is dimensioned in
18 such a way that additional electronic components of an evaluation unit can be arranged
19 thereupon. Relative to prior art, this makes it possible as a whole to dimension on a smaller
20 scale and more cost effectively. The evaluation unit can here perform a measured value
21 conversion for conditioning measured value signals for open-loop and closed-loop controllers,

1 running comparisons with limiting values and generating „too-low” or „too-high” messages,
2 or for other applications.

3 The multi-layer printed circuit board structure results in a symmetrical design for the
4 individual windings. In this case, the windings of the coil segment for the first winding
5 direction are arranged on two layers for the printed conductors provided exclusively for this
6 coil segment. With respect to the windings of the coil segment for the second winding
7 direction, e.g., return direction, there are two layers of printed conductors provided exclusively
8 for this coil segment. This makes more free space available for the geometric configuration
9 of the printed conductors.

10 The invention will be described based on an embodiment and the accompanying
11 figures below.

12 Captions to Figures

13 Fig.1: The device according to the invention of a current sensor with a flip-open, printed
14 circuit board-based current acquisition coil.

15 Fig. 2: The printed conductor progression for the coil segments involving the „go” path (20)
16 and the „return” path (21) of the winding.

17 Fig. 3: Flipped-open printed circuit board of the current acquisition coil.

1 Fig.4: A variant of the device of the current acquisition coil as a single-piece printed circuit
2 board with only one slot in the device, which can be placed around the conductor to
3 be measured for to open the printed circuit board via twisting.

4 Fig.5: A variant of the device of the current acquisition coil as a single-piece printed circuit
5 board with printed conductors and through plating to route through the current to be
6 measured.

7 Embodiment

8 Fig. 1 shows the arrangement according to the invention of a current sensor with a flip-
9 open, annular printed circuit board as the current acquisition coil. The hinge 6 provides a flip-
10 open link between the one printed circuit board half 1 and the second printed circuit board half
11 10. The current-carrying conductor 2 with its current to be measured is axially oriented and
12 routed through the middle of the current acquisition coil. The printed conductors of the
13 individual layers are not shown, but alluded to with 4 and 5. The additional part of the printed
14 circuit board 9 is preferably used to hold electric or electronic components for an evaluation
15 circuit 19, which issues a scaled measuring signal to the output 13.

16 Fig. 2 shows the arrangement of printed conductors for generating a current acquisition
17 coil. In this case, the printed conductors 22, 22a, 22b of the winding and the corresponding
18 additional printed conductors on the top of the incoming coil winding 20 are on the first layer.
19 The printed conductors 23, 23a, 23b along with the corresponding additional printed
20 conductors on the bottom of the incoming coil segment are located on the fourth layer, which
21 is isolated from all other layers. The printed conductors 24 and corresponding additional

printed conductors on the top for the returning coil segment 21 are located on the second layer, which is isolated from all other layers. The printed conductors 25 and corresponding additional printed conductors on the bottom for the returning coil segment are located on the third layer, which is isolated from all other layers. Since layers one and four are each arranged on the outside of the printed circuit board, while layers three and four are situated on the inside layers of the multi-layer printed circuit board, a returning coil segment 21 lying spatially in the incoming coil segment 20 comes about. Therefore, the incoming coil segment 20 is wound in the opposite direction as the returning coil segment 21.

Fig. 3 shows the flip-open printed circuit board of the current acquisition coil in the flipped-open state for enveloping the current-carrying conductor 2. The printed conductor parts 1 and 10 are here flipped open and spread apart until the current-carrying conductor 2 fits through the arising gap 11, and the current sensor can be passed over the current-carrying conductor in the direction of the arrow. The hinge 6 must here permit the rotational movement of individual printed circuit board halves or only one printed circuit board half necessary to achieve a maximal gap width 11. Flexible conductors 12 are used to electrically connect one half of the current acquisition coil 1 in direct proximity to the hinge 6 with the other half of the current acquisition coil 10 with the help of electrical terminals 13 in the manner required for current acquisition according to the Rogowski principle.

Fig. 4 shows a variant of a current acquisition coil to be opened on a single-piece, multi-layer printed circuit board, which has only one gap 7 as the unilateral opening for enveloping the current-carrying conductor 2. By applying a force to twist the printed circuit board, the gap 7 is widened to such an extent that the current-carrying conductor 2 can be moved in a radial direction through the gap. A printed circuit board segment 9 not used for

1 the coil preferably serves to hold electric or electronic components for an evaluation circuit
2 19, which issues a scaled measuring signal to the output 13.

3 Fig. 5 shows a single-piece current acquisition coil on a multi-layer printed circuit
4 board, in which the current-carrying conductor 52a, 54a is routed in an axial direction through
5 the printed circuit board as a through plating 53. The terminals are here routed via the current-
6 carrying printed conductor 52 to the incoming current-carrying conductor 52a, and via the
7 current-carrying printed conductor 54 to the continuing current-carrying conductor 54a. To
8 ensure that the current to be acquired is relayed in an axial direction through the printed circuit
9 board, the current-carrying printed conductors and printed circuit board terminals 56 are
10 arranged on the outside of the printed circuit board 1. In this configuration, the current-
11 carrying conductor is hooked up to the external current-carrying conductor parts 52a and 54a
12 via electrical connectors 56. A printed circuit board segment 9 not used for the coil is
13 preferably used to hold electric or electronic components for an evaluation circuit 19, which
14 issues a scaled measuring signal to the output 13. The arrangement shown on Fig.5 is
15 particularly advantageous for permanently fixed current sensors, which are no longer moved
16 around after installation.